Augmentation of FDV system at Hero Honda Motors Limited, Gurgaon

Prepared for **Hero Honda Motors Limited, Gurgaon**

TERI Project Report No. 2001IE67

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Executive Summary

Major findings of the study

- Existing FDV systems, which supply washed air to the various shops have been unable to provide required thermal comfort to the workers.
- The revised heat load calculation with added equipment load suggests that the rated air quantities of installed FDV systems are adequate except in one FDV system.
- Zone thermal comfort monitoring reveals that except heat treatment else every where temperature and relative humidity were close to recommended value but the air circulation rate was very poor. This led to the conclusion that the major cause of discomfort to the worker is air circulation rate since thermal comfort in an area is an integrated affect of air temperature, moisture content and air velocity.
- During initial inspection and air measurement at FDV rooms it was observed that the system was operating at less than half of the rated efficiency. The major causes of this inefficient system operation were prefilter and cellulose pad choking and damper settings. It was then suggested to overhaul the system since it was thought that if at all any system modification would be suggested it must have based on the optimum efficiency which could be achieved under prevailing circumstances.
- The measurement at supply grilles drew a picture of very unbalanced air distribution in zones.
- Overhauling of the existing FDV system improved the operating efficient of the system by approximately 10% but this optimum operation of the system still operates at a shade less than 60% of the rated efficiency of the systems.
- The air quantity which is required to provide for recommended air circulation rate inside the zone has been calculated and that appears to be unachievable with existing systems since rated fan capacity can not be achieved because of higher fiction loss in masonry ducts.
- Modification in terms of selecting and sizing a higher capacity fan to provide recommended room velocity is difficult since the present fiction losses in the masonry ducts cannot be ascertained.
- Air measurement at grilles shows that the masonry ducts are not balanced. Neither there is any provision to balance it.
- The air distribution within the space gets obstructed due to equipment layout.

- Based on results of all the measurement and analysis it has been found that it would be nearly impossible to enhance the efficiency of the existing FDV systems with area cooling to provide thermal comfort. Therefore it is concluded that the best way to meet the comfort criteria is spot cooling through overhead ducting must be used. Wherever additional air quantity is required a separate air washer should be installed on the terrace to provide the needed air quantity.
- In FDV-1 total required air quantity is found to be 160000 CFM out of which 110000 CFM is available with existing fans. This should be drawn from the FDV and distributed through overhead ducting in two rows. An air washer of 50000 CFM capacity should be installed on the terrace and air should be should be distributed through over head ducting in single row.
- FDV-2 which caters to Aluminum assembly, Frame assembly and Frame assembly inspection area appears to be in the worst state. Here the air, which is available with the existing fan, should to be taken out from the FDV and supplied through overhead in Aluminum phase. In addition to this a separate air washer of 25000 CFM is to be installed on the terrace and air should be supplied through overhead duct to cool the remaining Aluminum phase area.
- For Frame assembly a separate air washer system is recommended. Line-1 should be cooled with help of two air washers one of 50000 CFM & other of 30000 CFM which should be kept on the terrace and air should be distributed through overhead ducting. For line-2 two air washers one of 50000 CFM capacity and other one of 20000 CFM capacity should be installed on the terrace and air should be distributed suitably with the help of overhead ducting.
- In Frame assembly inspection area, two separate air washers are suggested. One with 25000 CFM at terrace with overhead ducting and another one with35000 CFM capacity again installed on the terrace and with overhead ducting to cool inspection area.
- For weld shop & press shop no additional air washer is recommended however measurement shows that in present modification air circulation is less as expected. Therefore is recommended to make a slight change in the arrangement at the fan discharge side. The three fans, which are kept at the top, should provide air exclusively to overhead duct and bottom three fans to underground duct, which is catering to the press shop.
- In FDV-4 system, existing air should be distributed through the overhead ducting in PPC WIP area, part of paint shop and frame sub assembly. An additional air washer of 60000-CFM capacity is recommended to install on

the terrace and air should be distributed through over head ducting in remaining area of the FDV.

- FDV-5 which provide cooling to heat treatment shop is quite inadequate to maintain comfortable condition to the area. Apart from area cooling through existing underground ducting additional air washer of 80000 CFM capacity is recommended to install on the terrace and cool area through spot cooling from overhead ducting.

Augmentation of Forced Draft Ventilation system at Hero Honda Motors Limited, Gurgaon

Introduction

Hero Honda Motors Limited (HHML) a joint venture between Hero Group, India and Honda Motor Company, Japan currently enjoys the status of world's no-1 company for two wheelers. In 2001-2002 company produced approximately 14.25 lakhs bikes and aims at a considerable rise in production this year. Being no-1 company HHML very clearly understands the relation between the work environment and productivity. At their Gurgaon unit it has been realised by the management based on the complaints made that the required thermal comfort has not been achieved in spite of various modifications and changes made at the existing space conditioning systems. In fact concerned authorities have been trying to rectify the problem for last five years but the results are far from the satisfactory. Being baffled by this situation the management finally decided to go for a detailed study of the existing systems and a final solution to resolve the problem.

Existing space cooling systems

Forced draft ventilation systems

The thermal comfort inside the unit is being provided with the rigid media type evaporative coolers popularly known as forced draft ventilation (FDV) systems. In this type of system ambient air is first sucked through pre filters and then passed through wet cellulose pads with the help of draw through centrifugal blowers. Cellulose pads generally consist of layers of corrugated cellulose paper, which have high water retention properties. These pads are constantly kept wet with the re-circulating water with a help of a pump. When the air passes through these pads, water gets evaporated by absorbing heat from air resulting in decrease in air temperature. The cooled air is called washed air, which is then carried to the zones through under ground duct network. In zones the cooled air is distributed through number of risers. Finally the air supplied in the zones is exhausted with suitable forced exhaust system. In the exhaust systems both axial fans and roof extractors are being used. However, the entire zone is designed, as

positive zone keeping the exhausted air approximately 50% and above of the supplied air.

This type of evaporative coolers is one of the most efficient ones and can achieve efficiency up to 90% and above. Since the evaporative type of cooler is hundred percent fresh air systems,

There are five separate FDV systems, which are cooling different areas in the unit as follows:

Table 1 Existing FDV system at HHML, Gurgaon

S No	FDV No	Area cooled by the FDV
1	FDV no-1	Steel phase
2	FDV no-2	Aluminium phase (old), Frame Assembly
3	FDV no-3	Press & weld shops
4	FDV no-4	Paint shop, Frame sub assembly, PPC WIP area
5	FDV no-5	Heat treatment

Cooling of new aluminium phase and gear section is being done with the help of air washers (FDV-6 & FDV-7) which are kept on the terrace and air inside the shops are being distributed by overhead GI ducts.

Design data

Outdoor conditions

Table 2 Outdoor design conditions for Gurgaon

S No	Season	Dry bulb temperature (DBT) ° C	Wet bulb temperature (WBT) ° C
1	Summer	45.0	24.0
2	Monsoon	35.0	28.3
3	Winter	7.2	5.0

Inside conditions

Summer and monsoon

Dry bulb temperature not to exceed than 9.3 ° C above outside wet bulb temperature.

Relative humidity (RH) not exceeding

Summer	60%
Monsoon	70%

Winter
Dry bulb temperature 20 °C
RH 40%

Equipment details

Ventilation Fans

Table 3 Areawise FVD fans details at HHML, Gurgaon

FDV no	Area	Area (m^2)	Height (m)	Volume (m^3)	No of blowers	Air quantity (CFM)
FDV no-1	Steel phase	2870	8	22960	6	243671
FDV no-2	Aluminium phase, Frame assembly	9555	8	76440	6	243671
FDV no-3	Press shop & weld shop	4725	10.25	48650	6	243671
FDV no-4	Paint shop, frame sub assembly	5400	10	54000	5	136844
FDV no-5	Heat treatment	1350	10	13500	4	109475

Exhaust fans & Roof extractors

Table 4 Areawise details of exhaust fans and roof extractors at HHML, Gurgaon

S No	Area	No of fans	Air quantity (CFM)
1	Steel phase	3	121835
2	Aluminium phase, Frame assembly	3	121835
3	Press shop & weld shop	3	121835
4	Heat treatment	13	91819
5	Vehicle despatch store	12	155388
6	Component store	4	51796
7	Weld shop	2	10594
8	Engine assembly	4	7768
9	Canteen	3	21189

Heat load calculation

Since the FDV systems were designed at the inception of the unit and after that new equipment load and lighting load have been added. In order to see the impact of added load on the FDV systems and check the adequacy of the existing system, heat load of all the areas have been recalculated based on the new light and equipment load data furnished by the HHML. FDV-wise detailed break-up of new loads is given below.

The design outdoor and indoor conditions are kept same as considered earlier.

Table 5 Input data provided by HHML for load calculation

S No	Area	Load Mar 01 (kW)	Added load (kW)	Max plant load factor (%)	Max operating lighting load (kW)
1	Steel phase	810	252	26.32	22
2	Aluminium phase	781	297	27.17	16
3	Heat treatment	1470	110	41.14	10
4	Frame Assembly	130	0	46.15	45
5	Press shop	262	0	26.72	7
6	Weld shop	1100	525	24.56	11

Present Heat load of FDVs

FDV-1

S No	Component	Heat gain (Btu/hr)
1	Wall	0
2	Roof	143663
3	Light	93830
4	Equipment	1091840
5	Other	0
6	Total load	1329333

FDV-2

S No	Component	Heat gain (Btu/hr)
1	Wall	134299
2	Roof	376690
3	Light	162070
4	Equipment	1194200
5	Other	0
6	Total load	1867259

FDV-3

S No	Component	Heat gain (Btu/hr)
1	Wall	76346
2	Roof	172174
3	Light	76770
4	Equipment	1910720
5	Other	0
6	Total load	2236010

FDV-4

S No	Component	Heat gain (Btu/hr)
1	Wall	82556
2	Roof	315403
3	Light	187660
4	Equipment	2149560
5	Other	0
6	Total load	2735179

FDV-5

S No	Component	Heat gain (Btu/hr)
1	Wall	137645
2	Roof	85791
3	Light	42650
4	Equipment	2217800
5	Other	34374
6	Total load	2518260

Required air quantity based on present load

Air quantity need to be supplied is calculated based on the present load and design data of present FDV system. 90% saturation efficiency is considered and a temperature difference of 14 ° F between washed air and room temperature is considered for the calculation of air quantity.

Table 6 Air quantity required for present load

FDV	Air quantity required (CFM)
FDV no-1	88000
FDV no-2	124000
FDV no-3	148000
FDV no-4	181000
FDV no-5	167000

As per new heat load calculation the total amount of air quantity required is approximately 708000 CFM which is less than the rated air quantity of 977332 CFM.

Required air quantity v/s rated air quantity

After calculating the amount of air required for cooling the space as per new heat load a comparison of new air quantity with rated air quantity in each FDV area is made and presented in the table no-6 below.

Table 7 Comparison of required air quantity (CFM) for meeting present load with rated air quantity

FDV	Rated CFM	Required CFM	Remark
FDV no-1	243671	88000	Rated air quantity is quite high as compared to the required air quantity. No need to add extra blowers.
FDV no-2	243671	124000	Rated air quantity is quite high as compared to the required air quantity. No need to add extra blowers.
FDV no-3	243671	148000	Rated air quantity is quite high as compared to the required air quantity. No need to add extra blowers.
FDV no-4	136844	181000	Required air quantity is more fan capacity needs to be increased
FDV no-5	109475	167000	Required air quantity is more fan capacity needs to be increased

Thermal comfort

Most people seem comfortable when they are maintaining normal body temperature (37 ° C) without expending energy to counteract either gain or loss of body heat. Body processes generally convert the food energy in to heat. About 90% of calories consumed eventually end up as heat. This heat is dissipated through the skin and lungs. This metabolic heat varies in amount with the degree of activity and the size of the body. Approximately 800 to 1000 Btuh heat to be removed at 25.6 ° C air if person is working in a factory. If the heat is not removed, it raises the body temperature above it's normal and causes acute discomfort. If, on the other hand, the heat is lost faster than it is generated, causing body extremities and surface to fall in temperature, the environment is experienced as too cold.

Therefore "Comfort" results when the environment accepts heat exactly at its rate of production. The point of balance varies with individual activity, metabolism, and clothing. The interaction of levels of air movement, air temperature, mean radiant temperature and relative humidity are also important.

When the surrounding air is below 34.4 ° C, as in the case of evaporative cooling, the body dissipates metabolic heat by convection and radiation and only occasionally by actual conduction. At higher temperatures, the body gains instead of lose heat by those means causing increased distress. The evaporative cooling by the skin and respiratory tract is effective at all temperatures that cause perspiration. However, evaporation rates are governed largely by the air's relative humidity and velocity of motion. The latter also affects convection rates and so has special importance.

Thus, with the matters of clothing and radiation distances ignored, the key factors governing the human body's dissipation of metabolic heat, and therefore its comfort are as follows:

- Temperature of air
- Temperature of walls, ceilings or other surroundings
- Relative humidity of air
- Circulating velocity of air

To achieve thermal comfort in air cooled area it is recommend to have temperature less than 34 ° C, relative humidity in the range of 20% to 70 % and room velocity less than 200 fpm for sedentary workers and 300 fpm for factory workers.

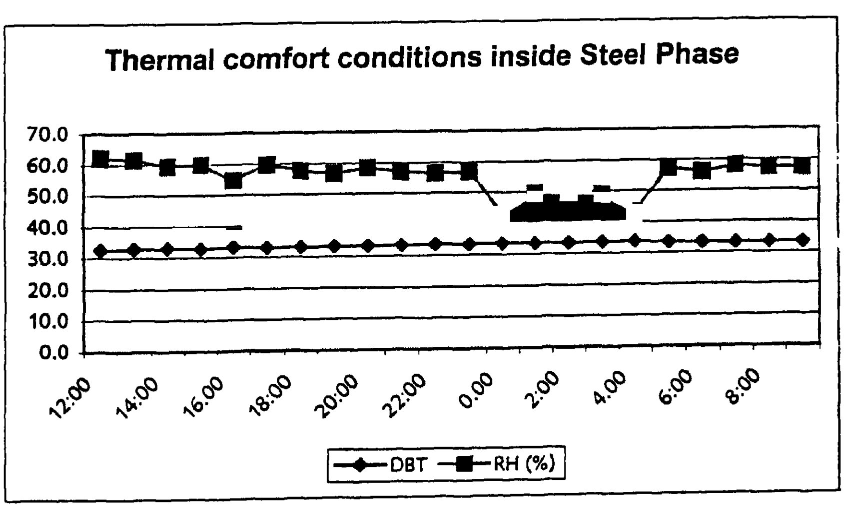
Measurements & Observations

Temperature & Humidity measurements inside the unit

Hourly temperature and RH were measured with the help of data loggers at various points in order to assess the thermal comfort conditions in each important area. The graphs showing temperature and RH variation are given below.

Steel phase

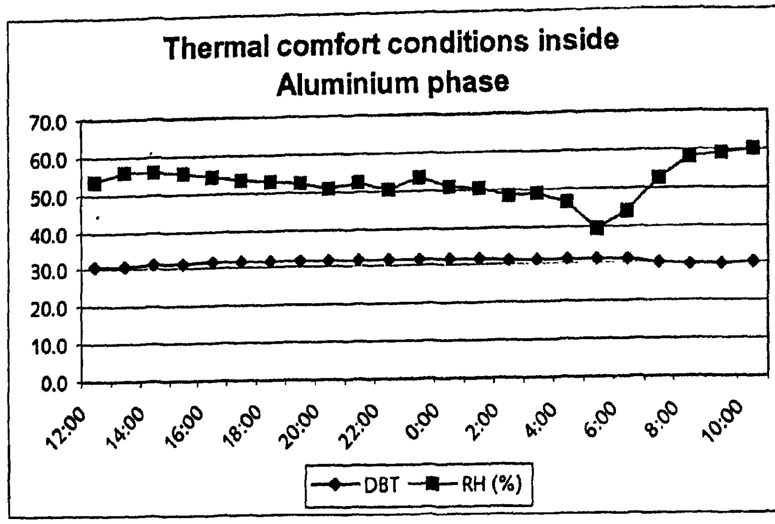
- Mean temperature : 33.2 ° C
- Mean RH : 55.5%



- The above temperatures & RH show that the condition inside the steel phase is generally close to the design values.

Aluminium phase

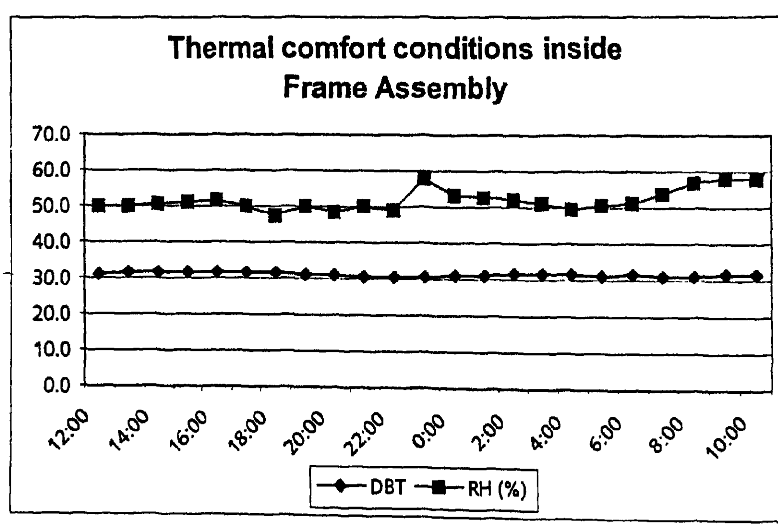
- Mean temperature : 31.2 ° C
- Mean RH : 52.1 %



- The above temperatures & RH show that the condition inside the aluminium phase is generally close to the design values.

Frame assembly

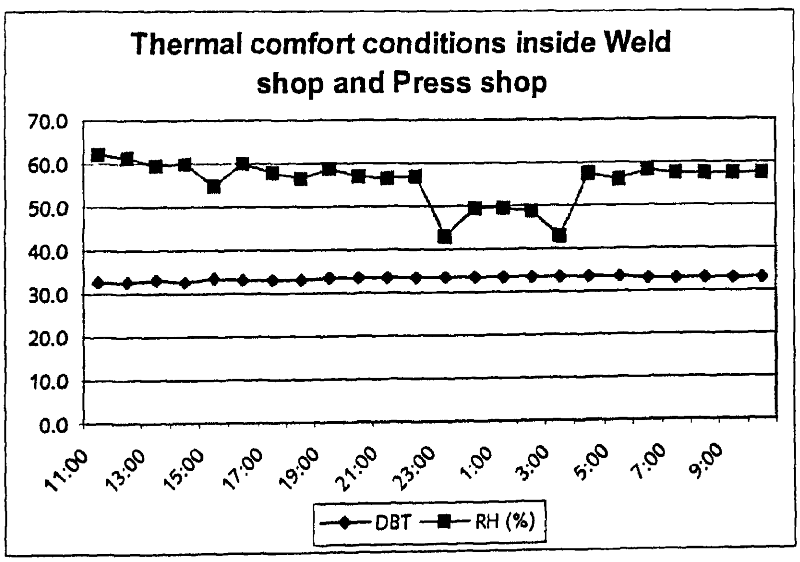
- Mean temperature : 31.2 °C
- Mean RH : 51.8 %



- The above temperatures & RH show that the condition inside the Frame assembly is generally close to the design values.

Press shop & Weld shop

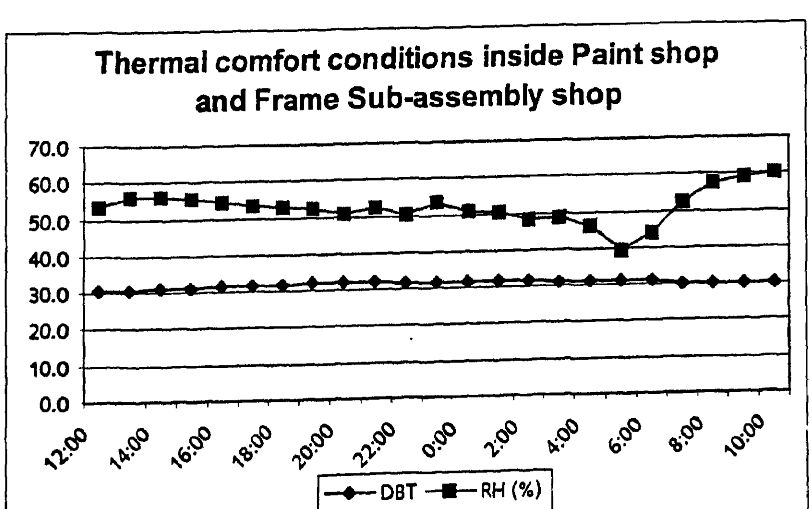
- Mean temperature : 33.2 ° C
- Mean RH : 55.7 %



- The above temperatures & RH show that the condition inside the Press shop & weld shop is generally close to the design values.

Paint shop & Frame sub-assembly

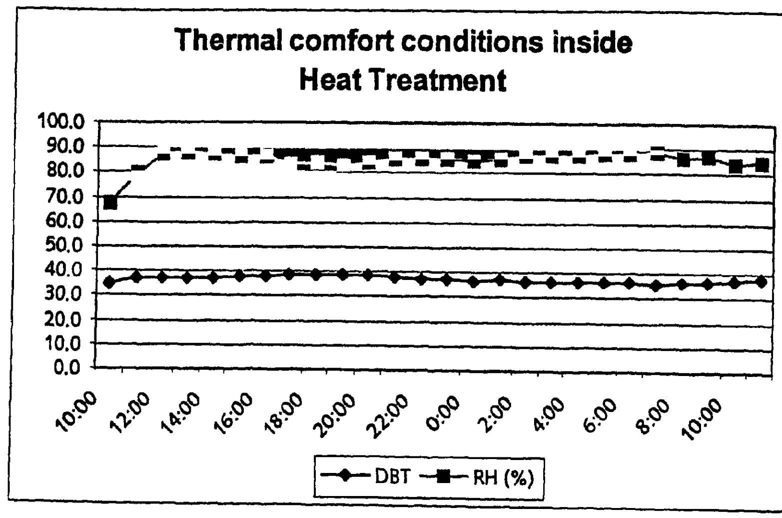
- Mean temperature : 31.2 ° C
- Mean RH : 52.1 %



- The above temperatures & RH show that the condition inside the Paint shop & Frame sub assembly generally remains within the design range.

Heat treatment

- Mean temperature : 37.2 °C
- Mean RH : 86 %



- The above graph shows the temperatures & RH values generally remain above the design value. This will cause a great deal of discomfort within the heat treatment.

Air velocity & Air quantity measurement at FDV systems

As explained in the thermal comfort section to achieve comfort its not only temperature and humidity but air velocity also plays a very important role. For removing heat from the zones sufficient quantity of air should also be circulated. In order to find out how much air being circulated and at what velocity, a very comprehensive measurement was carried out. Air velocities were measured at all the grilles and register and by multiplying with the corresponding areas the total air quantity being circulated in each FDV were calculated. All the measurement details are summarised below:

FDV-1 (Steel Phase)

At FDV

Average air velocity at pre-filters 159 ft/min

Quantity of air sucked at pre-filters	:	78560 CFM

Inside Steel Phase

Average air velocity at wall grilles/riser registers	:	903 ft/min
Total quantity of air supplied	:	75320 CFM

FDV-2 (Aluminium Phase & Frame Assembly)

At FDV

Average air velocity at pre-filters	:	186 ft/min
Quantity of air sucked at pre-filters	:	89150 CFM

Inside Aluminium Phase

Average air velocity at wall grilles/riser registers	:	1053 ft/min
Total quantity of air supplied	:	60450 CFM

Inside Frame Assembly

Average air velocity at wall grilles/riser registers	:	496 ft/min
Total quantity of air supplied	:	19840 CFM

FDV-3 (Press Shop & Weld Shop)

At FDV

Average air velocity at pre-filters	:	248 ft/min
Quantity of air sucked at pre-filters	:	121760 CFM

Inside Press Shop

Average air velocity at wall grilles/riser registers	:	1127 ft/min
Total quantity of air supplied	:	37720 CFM

Inside Weld Shop

Under Ground distribution

Average air velocity at wall grilles/riser registers	:	185 ft/min
Total quantity of air supplied	:	11460 CFM

Over head distribution

Average air velocity at grilles	:	443 ft/min
Total quantity of air supplied	:	53900 CFM

FDV-4 (Paint Shop, PPC WIP Area & Frame Sub-assembly)

At FDV

Average air velocity at pre-filters : 137 ft/min
Quantity of air sucked at pre-filters : 13640 CFM

Inside Paint Shop

Average air velocity at wall grilles/riser registers : 341 ft/min
Total quantity of air supplied : 13640 CFM

FDV-5 (Heat Treatment)

At FDV

Average air velocity at pre-filters : 273 ft/min
Quantity of air sucked at pre-filters : 65500 CFM

Inside Heat Treatment Plant

Average air velocity at wall grilles/riser registers : 721 ft/min
Total quantity of air supplied : 62400 CFM

Comparison of measured air quantity with rated air quantity

Table 8 Measured and rated air quantities

FDV	Rated CFM	Measured CFM	Remark
FDV no-1	243671	76000	Operating air quantity is just 31% of the rated air quantity
FDV no-2	243671	89000	Operating air quantity is just 37% of the rated air quantity
FDV no-3	243671	120000	Operating air quantity is 49% of the rated air quantity
FDV no-4	136844	41000	Operating air quantity is very low, just 30% of the rated air quantity
FDV no-5	109475	63000	Operating air quantity is 58% of the rated air quantity

The total measured air quantity is found to be 389000 CFM that is 40 % of the total rated air quantity of 977332 CFM.

During air quantity measurements it was observed that the maintenance of the systems were not as required. Filters were found choked, there was a lot of deposition of mud and algae in the cellulose pad, discharge dampers of blowers were not holding as well as the canvas on the discharge side of the fans were

torn. It was brought into the notice of HHML management and then it was decided that first the complete overhauling of the FDV systems would be done. Later on fresh measurement of air quantity would be carried out since it was thought that it would not wise to suggest any improvements on the systems in such working conditions since there exists a scope to improve it little bit.

Air quantity measurement at overhauled FDV systems

FDV-1 (Steel Phase)

At FDV

Average air velocity at pre-filters	:	208 ft/min
Quantity of air sucked at pre-filters	:	100000 CFM
Fan static	:	1.72" of WG

FDV-2 (Aluminium Phase & Frame Assembly)

At FDV

Average air velocity at pre-filters	:	292 ft/min
Quantity of air sucked at pre-filters	:	124000 CFM
Fan static	:	1.9" of WG

FDV-3 (Press Shop & Weld Shop)

At FDV

Average air velocity at pre-filters	:	354 ft/min
Quantity of air sucked at pre-filters	:	148000 CFM
Fan static	:	1.8" of WG

FDV-4 (Paint Shop, PPC WIP Area & Frame Sub-assembly)

At FDV

Average air velocity at pre-filters	:	197 ft/min
Quantity of air sucked at pre-filters	:	63000 CFM
Fan static	:	2.1" of WG

FDV-5 (Heat Treatment)

At FDV

Average air velocity at pre-filters	:	346 ft/min
Quantity of air sucked at pre-filters	:	346 CFM
Fan static	:	1.7" of WG

Comparison of air measured air quantities before and after the overhauling of the FDVs

Table 9 Initial operating air quantity & improved operating air quantity after overhauling

FDV	Initial measured air quantity (CFM)	Measured air quantity after overhauling (CFM)	Remark
FDV no-1	76000	100000	Air quantity gets increased by 32%
FDV no-2	89000	140000	Air quantity gets increased by 57%
FDV no-3	120000	170000	Air quantity gets increased by 42%
FDV no-4	41000	63000	Air quantity gets increased by 54%
FDV no-5	63000	83000	Air quantity gets increased by 32%

- After overhauling the measured total air quantity found to be 556000 CFM which is 43% more than the initial measured total air quantity.
- The operating total air quantity after over hauling is just 57% of the rated total air quantity and 79% of the required total air quantity as per new heat loads.
- The measured air quantity after over hauling of FDVs is considered to be the best output that can be drawn from the existing FDVs under prevailing conditions.

Observation

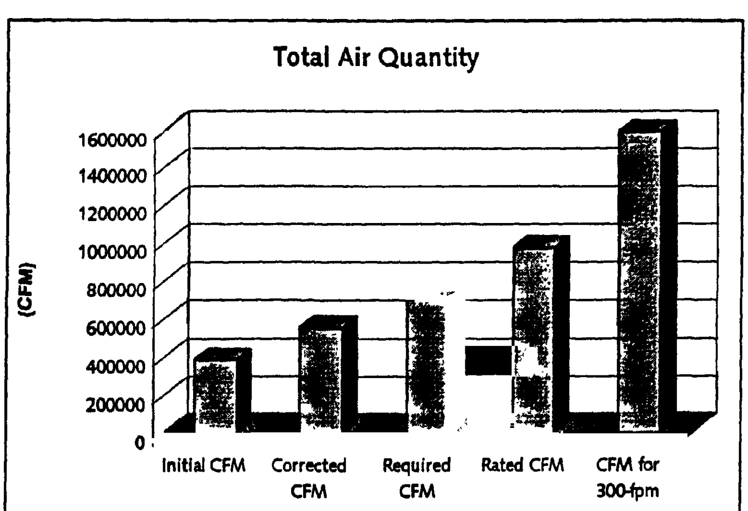
The graphs and data given in section above indicate that the temperature and the RH in all the areas except heat treatment remains within the design parameters. However, it also evident that from the diagrams given in appendix-1 the air velocity near the worker is no where could be found close to the recommended value (300 fpm) in fact it was observed very low (in the range of 15 to 80 fpm). That is why in spite of adequate temperature and humidity the workers find the working environment very uncomfortable. This leads to the conclusion that the velocity at which air is striking the human body needs to be increased.

Calculation of air quantity need to be supplied to give 300 fpm room velocity

The air quantity measurement revealed that the quantity of air which was supplied by the fans were very less as compared to the rated values. They remained less even after completely overhauling the systems. That suggests that in order to provide comfort the air quantity being supplied should be increased but how much? Above measured parameters and description also suggest that for getting a comfortable conditions inside unit an interactive balance of temperature, relative humidity and air velocity has to be maintained. Since temperature and relative humidity are not much of a problem the only parameter which needs to be addressed is air velocity. So it concludes that if a system can give an average velocity of 300 fpm near the worker it will be able to provide comfortable condition inside the unit. Hence a back calculation is done to find out the quantity of air which is to be supplied through each FDV to give 300-fpm velocity at the zone. The results are given below:

Table 10 Air quantity to be supplied based on 300-fpm room velocity

FDV no	Air Quantity (CFM)
FDV no-1	180000
FDV no-2	590000
FDV no-3	325000
FDV no-4	268000
FDV no-5	232000



Initial CFM	:	total measured air quantity before the overhauling of FDVs
Corrected CFM	:	total measured air quantity after the overhauling of FDVs
Required CFM	:	total air quantity required based on new heat loads
Rated CFM	:	total installed capacity of FDVs
CFM for 300-fpm	:	total air quantity required to give 300 fpm room velocity with existing FDV system

Major problems in present FDV systems

1. In spite of best maintenance efforts the existing fans are delivering only 57% of their rated capacity.
2. Rated fan capacity can not be achieved because of higher fiction loss in masonry ducts.
3. Modification in terms of selecting and sizing a higher capacity fan to provide recommended room velocity is difficult since the present fiction losses in the masonry ducts cannot be ascertained.
4. Air measurement at grilles shows that the masonry ducts are not balanced. Neither there is any provision to balance it.
5. The air distribution within the space gets obstructed due to equipment layout.

Recommendations

Based on all the facts it becomes certain to modify the existing systems. Facts reveal that area cooling through under ground ducting is a complete failure. Hence it decided and recommended to change the area cooling from existing under ground ducting to spot cooling from over head ducting. Following measures are suggested for each area.

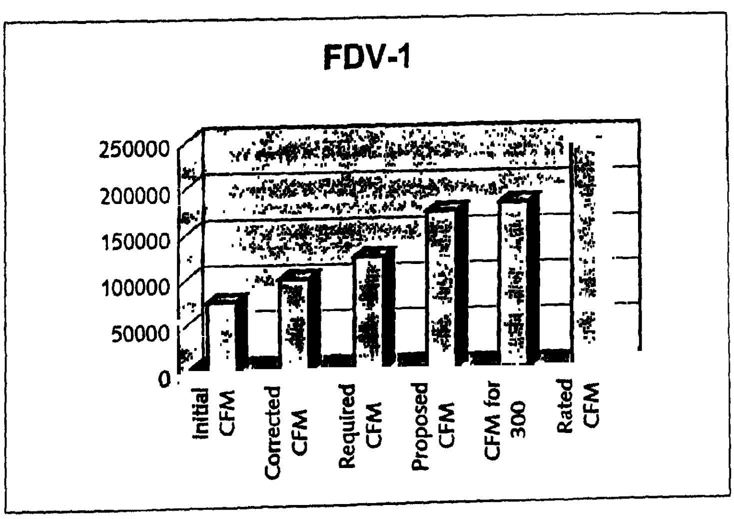
Spot cooling design criteria

Recommended CFM	:	1000 per person
Grill velocity	:	1200 to 1500 fpm
Spot velocity	:	500~ fpm

FDV -1

It has been observed that in steel phase area air supply through underground ducting is uneven and not very effective. It is recommended to close the underground duct and take the air supply from the top of the FDV-1 and distribute through overhead ducting in the part of steel phase to provide required thermal comfort as shown in drawing no-2.

In addition to the existing FDV system operational at present, install an air washer system of 60000 CFM at terrace and lay overhead ducting in the remaining part of steel phase to provide required comfort condition as shown in drawing no-3.



FDV -2

For Frame Assembly

Install a separate air washer system, one of 50000 CFM and one of 30000 CFM at terrace and lay overhead ducting in the frame assembly line-1 area to provide required comfort condition as shown in drawing no-6.

Install a separate air washer system, one of 50000 CFM and one of 20000 CFM at terrace and lay overhead ducting in the frame assembly line-2 area to provide required comfort condition as shown in drawing no-7.

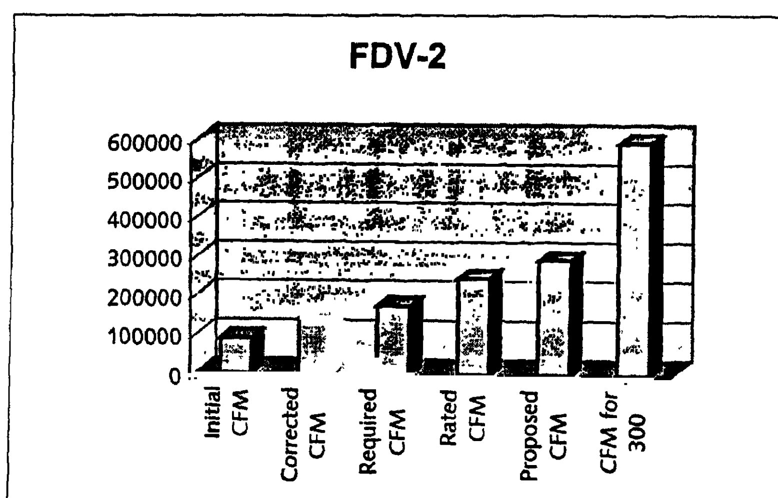
Install a separate air washer system of 25000 CFM at terrace and lay overhead ducting in the frame assembly inspection area to provide required comfort condition as shown in drawing no-8.

Install another air washer system of 35000 CFM at terrace and lay overhead ducting in the remaining frame assembly inspection area to provide thermal comfort as shown in drawing no-9

For Aluminium Phase Assembly

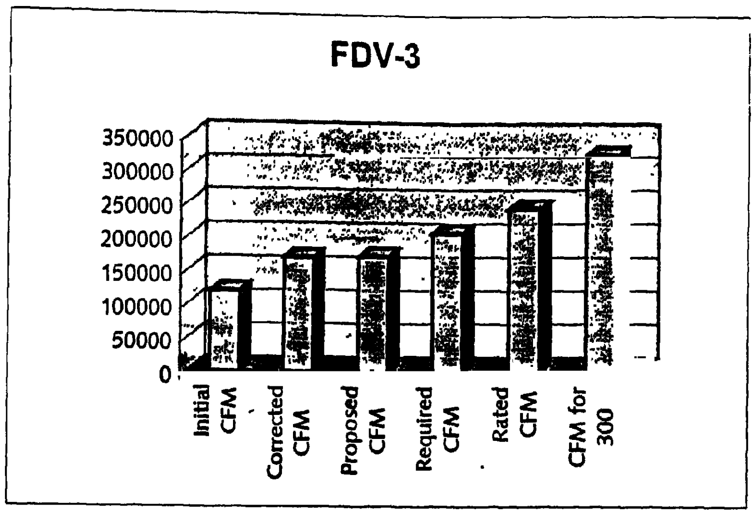
Since the air supply through underground ducting is uneven and ineffective it is recommended to close the underground duct and take the air supply from the top of the FDV-2 and distribute through overhead ducting in the Aluminium phase to provide required thermal comfort as shown in drawing no-4.

Install an additional air washer system of 25000 CFM at terrace and lay overhead ducting in the remaining aluminium phase area to provide thermal comfort as shown in drawing no-5.



FDV -3

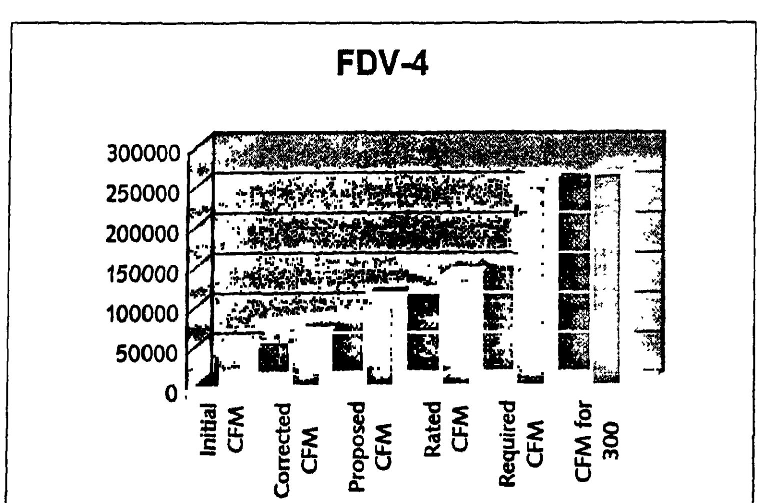
In weld shop washed air is being supplied through underground ducting as well as overhead ducting. It was observed that was not getting equally distributed in overhead and underground ducting. It was therefore recommended to have dedicated air supply for each type of ducting. In which the upper floor fans should supply air to overhead ducting and ground floor fans to the underground ducting.



FDV -4

In paint shop area air supply through underground ducting is uneven and not very effective in entire area. It is recommended to close the underground duct and take the entire air supply from the top of the FDV-4 and distribute through overhead ducting in the part of paint shop and frame sub assembly to provide required thermal comfort as shown in drawing no-11.

In addition to the existing FDV system, install an air washer system of 60000 CFM at terrace and lay overhead ducting in the remaining part of paint shop & frame sub assembly to provide required comfort condition as shown in the drawing no-10.



FDV -5

In addition to the existing FDV system operational at present, install an air washer system of 80000 CFM at terrace and lay overhead ducting in the heat treatment plant to meet the present load as shown in the drawing no-1.

